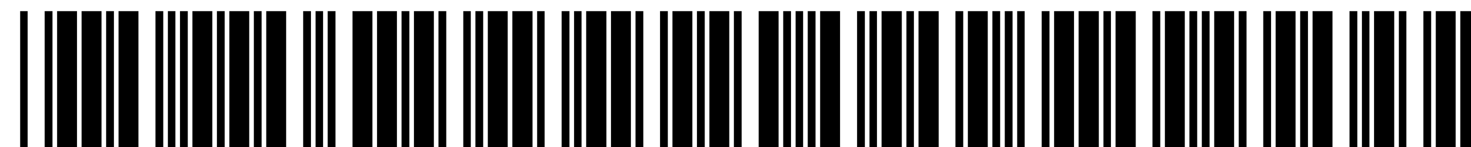

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Wu et al.

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(54) **LENS ADJUSTMENT FOR AN EDGE EXPOSURE TOOL**

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G03F 7/00 (2006.01)
G03F 7/20 (2006.01)

(52) **U.S. Cl.**
CPC ***G03F 7/70141*** (2013.01); ***G03F 7/203*** (2013.01); ***G03F 7/2028*** (2013.01)

(58) **Field of Classification Search**
CPC G03F 7/2028; G03F 7/70833; G02B 7/04; G02B 7/09; G02B 7/10; G02B 7/102
See application file for complete search history.

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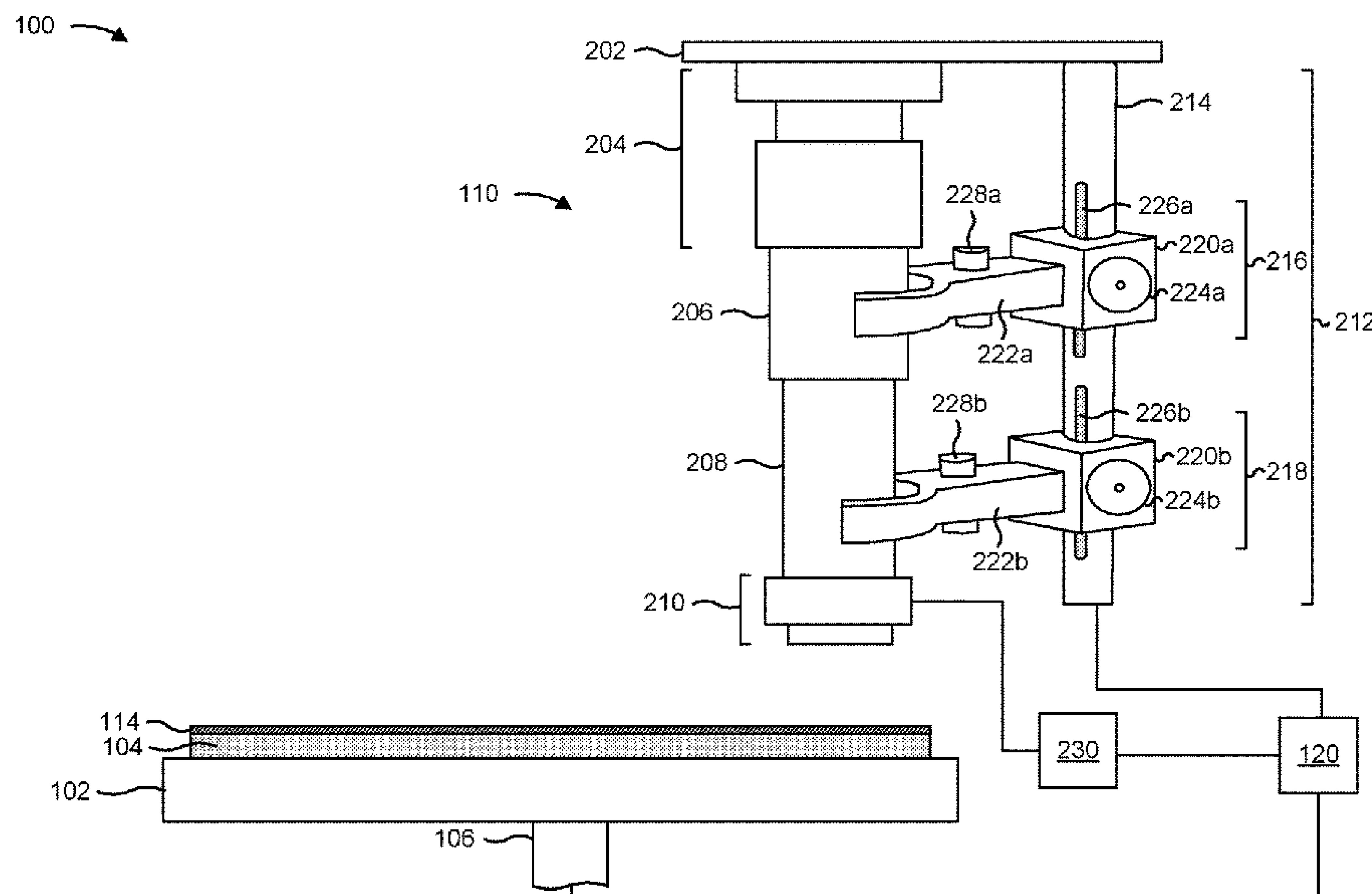
(57) **ABSTRACT**

An edge exposure tool may include a lens adjustment device that is capable of automatically adjusting various parameters of an edge exposure lens to account for changes in operating parameters of the edge exposure tool. In some implementations, the edge exposure tool may also include a controller that is capable of determining edge adjustment parameters for the edge exposure lens and exposure control parameters for the edge exposure tool using techniques such as big data mining, machine learning, and neural network processing. The lens adjustment device and the controller are capable of reducing and/or preventing the performance of the edge exposure tool from drifting out of tolerance, which may maintain the operation performance of the edge exposure tool and reduce the likelihood of wafer scratching, and may reduce the down-time of the edge exposure tool that would otherwise be caused by cleaning and calibration of the edge exposure lens.

20 Claims, 8 Drawing Sheets



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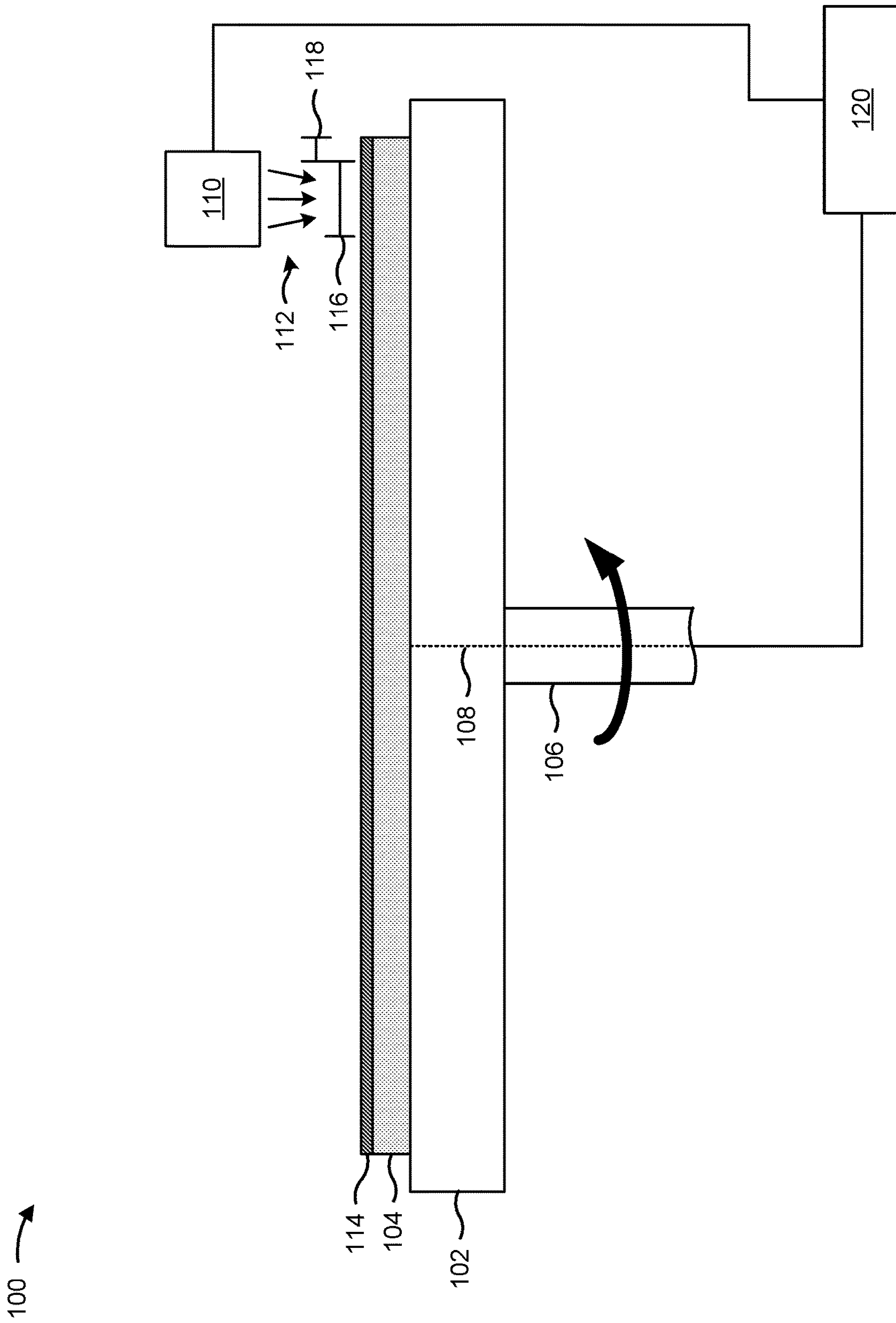

FIG. 1

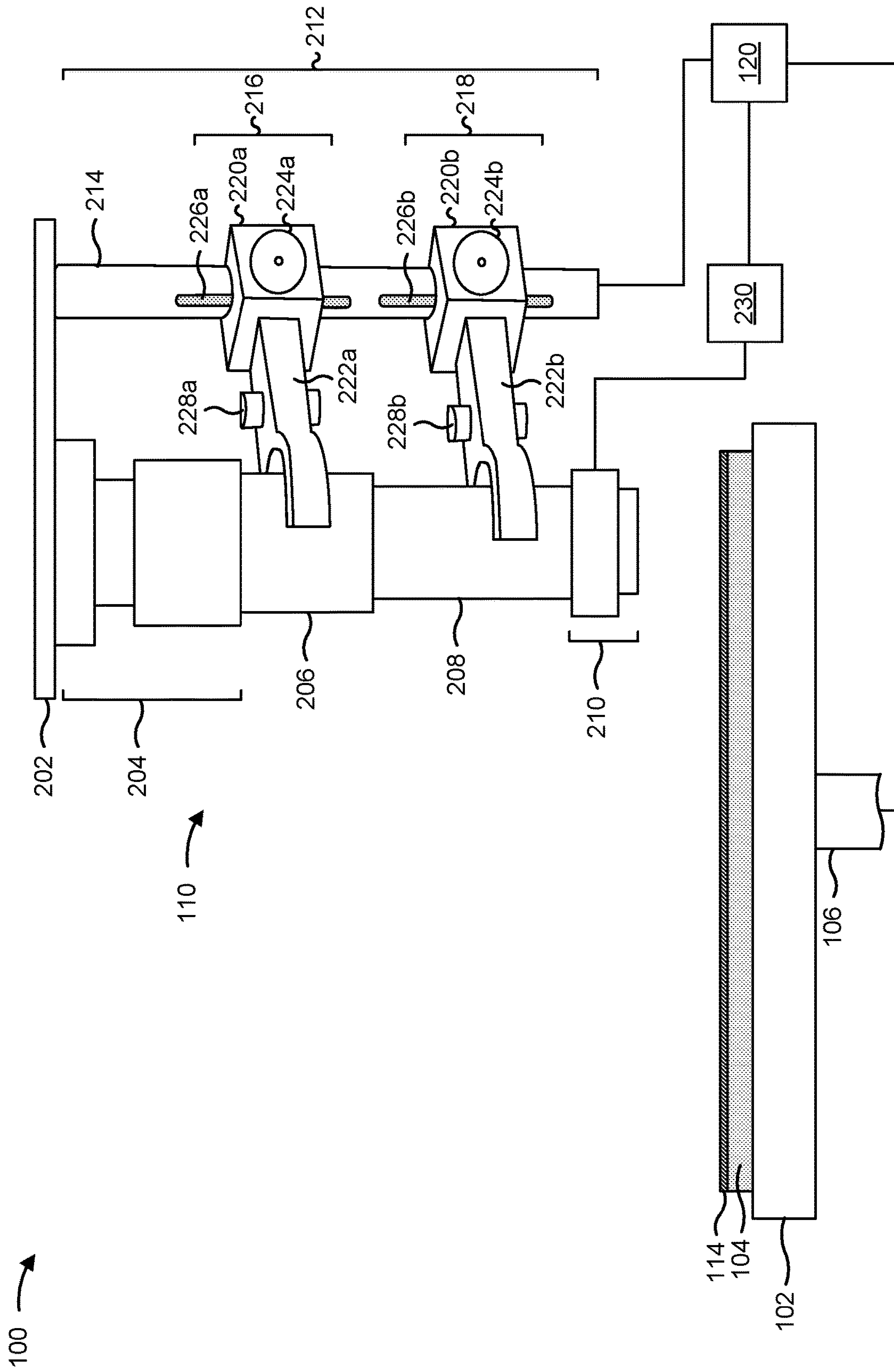

FIG. 2

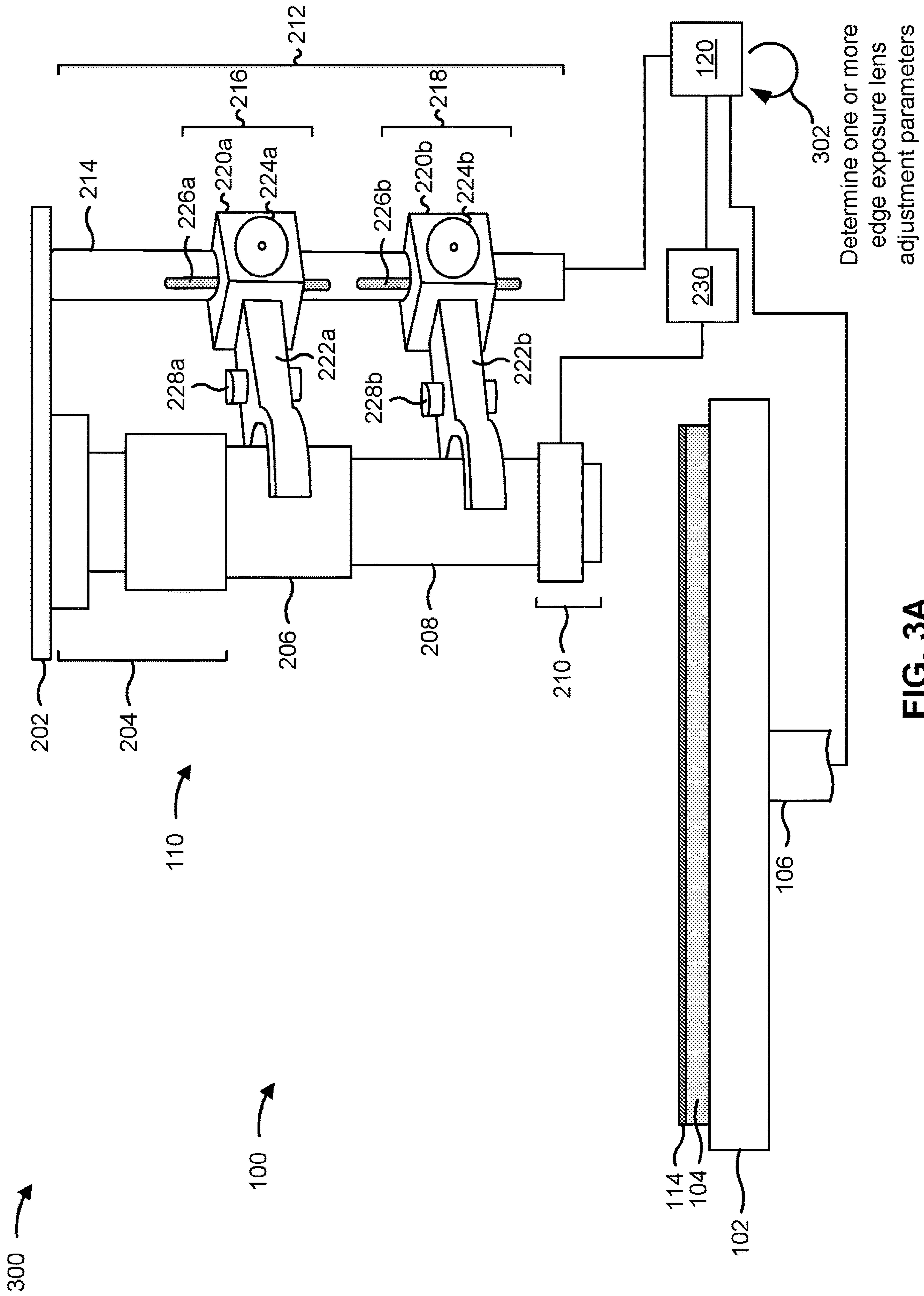

FIG. 3A

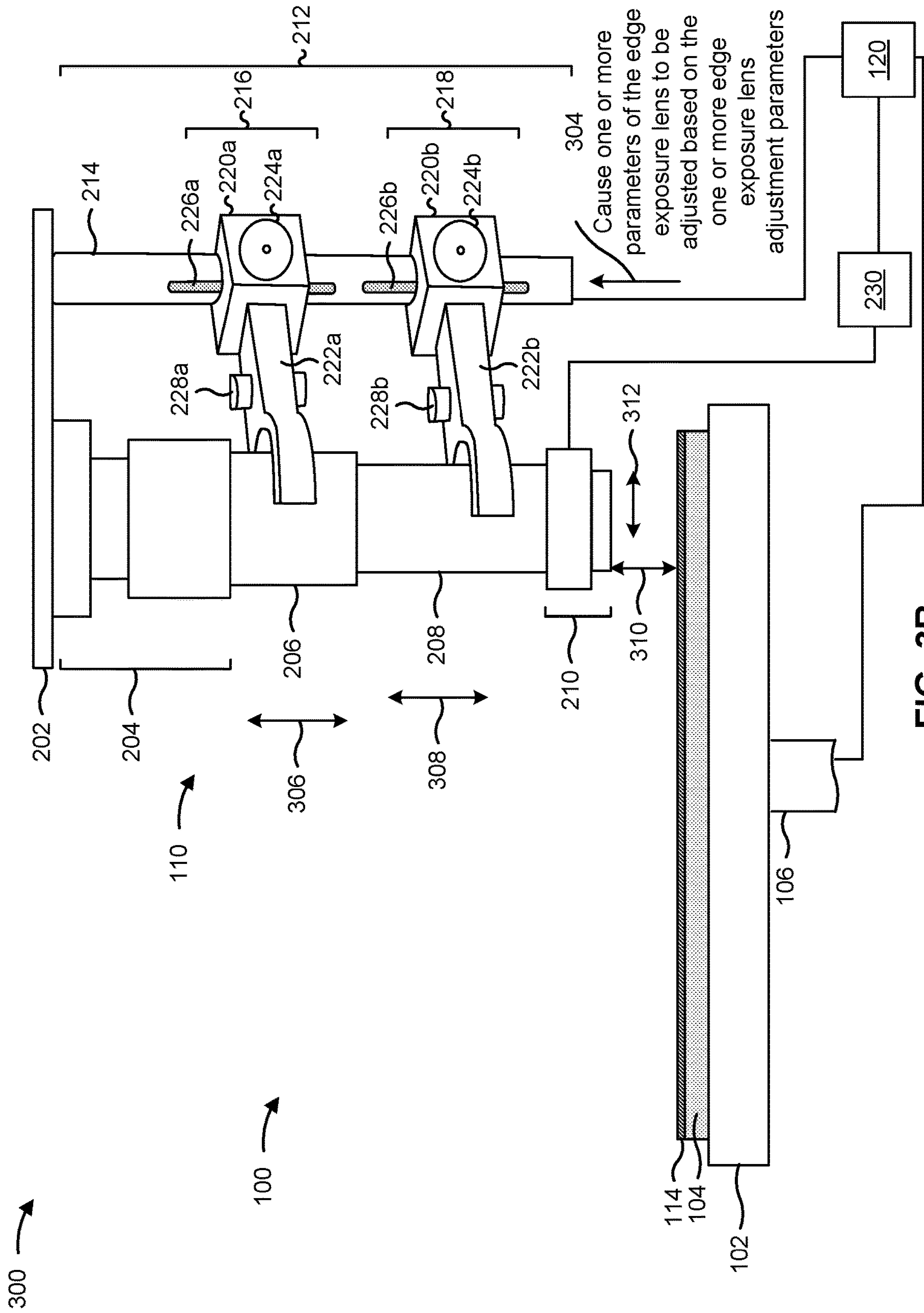

FIG. 3B

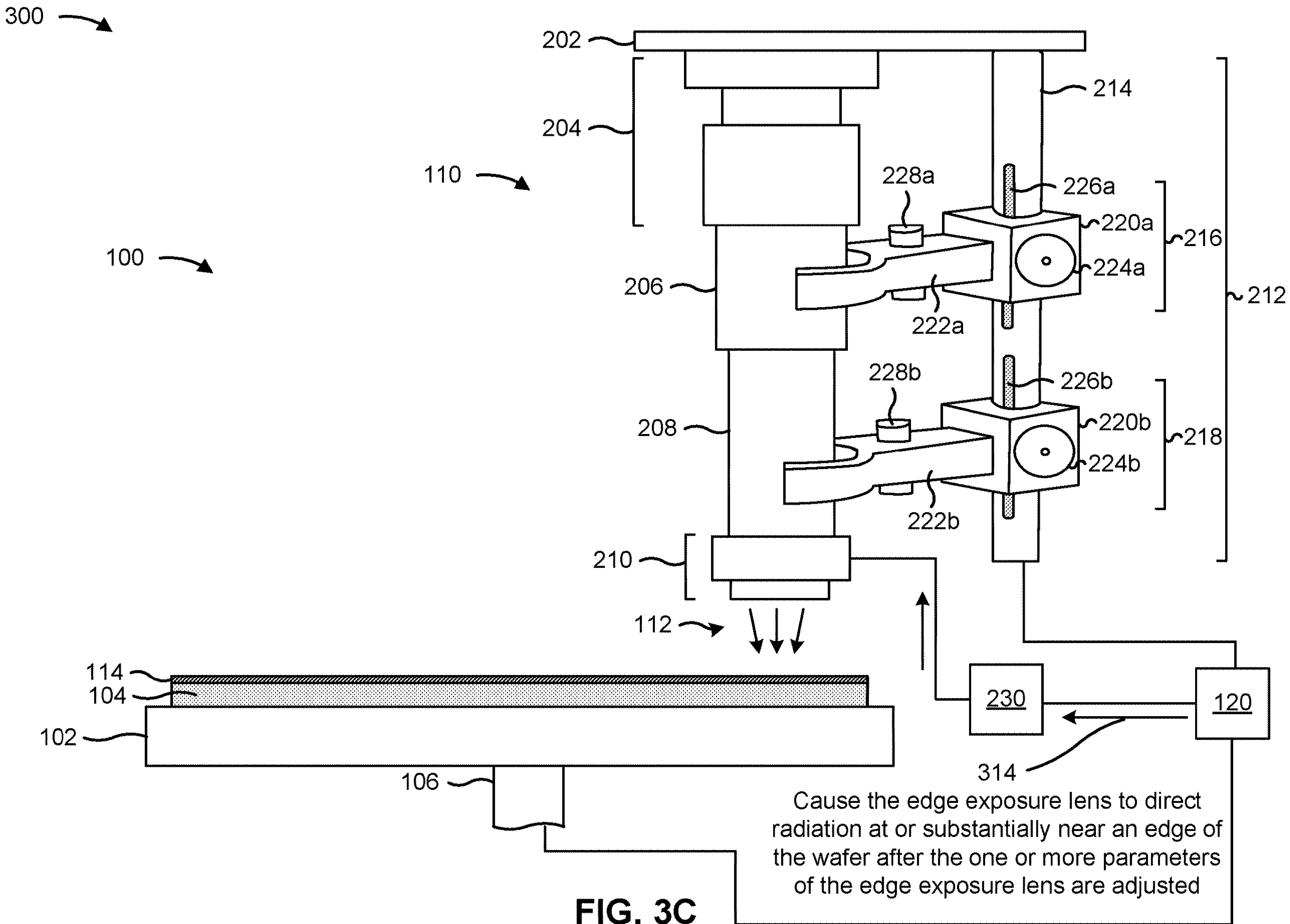

FIG. 3C

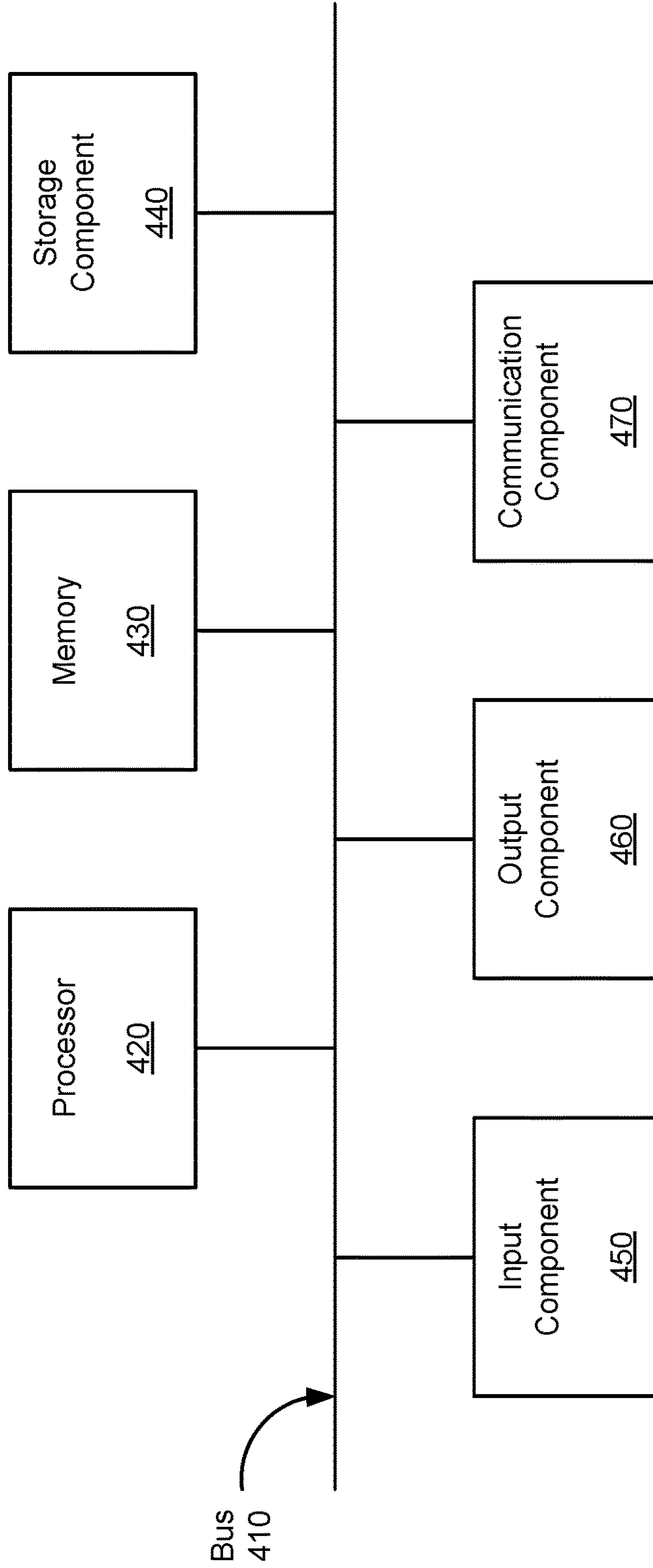

FIG. 4

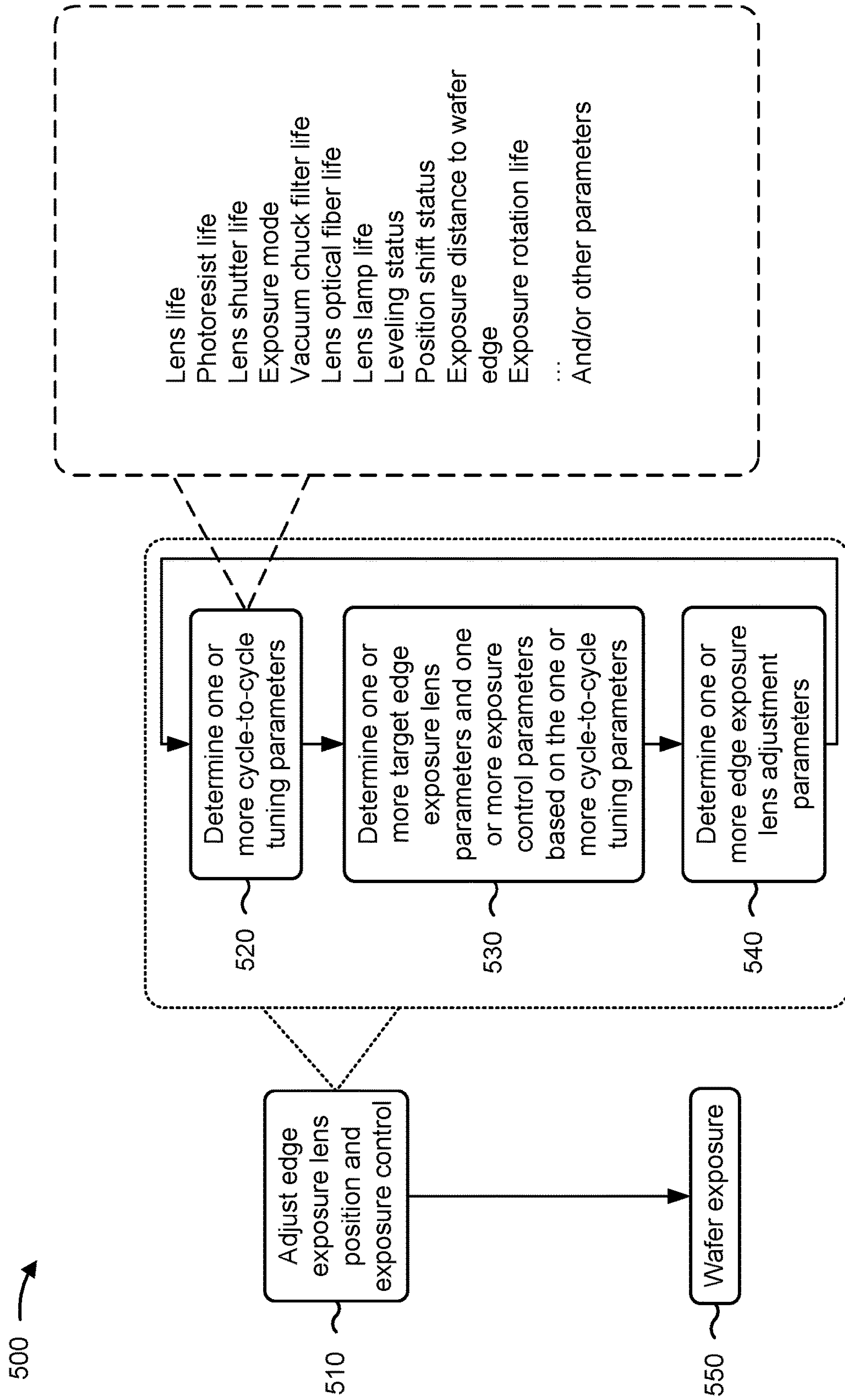

FIG. 5

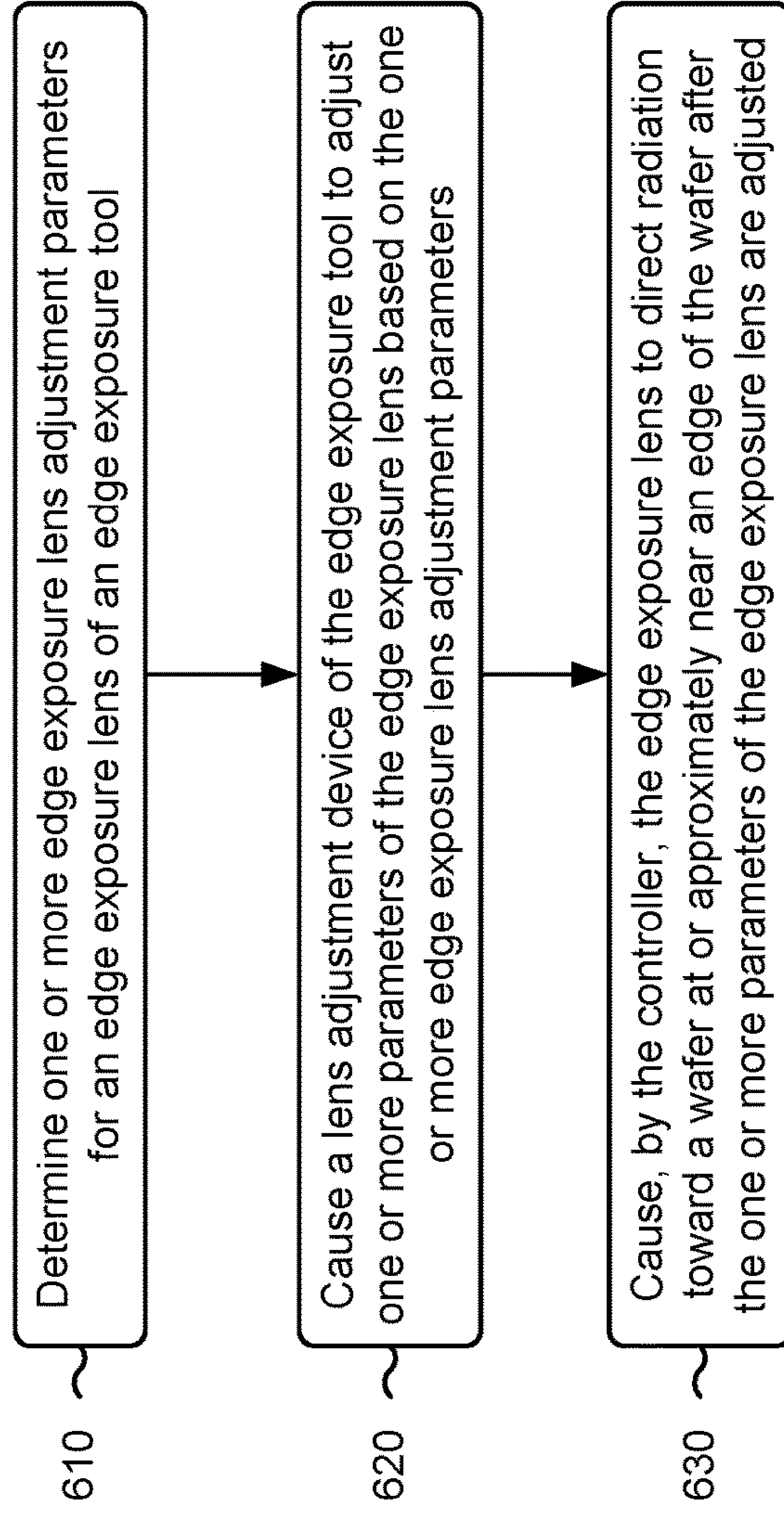

FIG. 6

LENS ADJUSTMENT FOR AN EDGE EXPOSURE TOOL

RELATED APPLICATION

This application is a continuation of U.S. patent application Ser. No. 17/248,074, filed Jan. 7, 2021 (now U.S. Pat. No. 11,378,888), which is incorporated herein by reference in its entirety.

BACKGROUND

A wafer edge exposure (WEE) tool is a semiconductor processing tool that is capable of processing an edge of a wafer along an outer perimeter of the wafer. As an example, a WEE tool may be used to expose a photoresist layer on the edge to seal the edge of the wafer while leaving the remaining portions of the photoresist layer unexposed, which may protect the edge of the wafer contaminants. As another example, a WEE tool may be used to expose a photoresist layer on the edge of the wafer to expose alignment marks covered by the photoresist layer, which permits the wafer to be aligned during subsequent semiconductor processes.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures. It is noted that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIGS. **1** and **2** are diagrams of an example edge exposure tool described herein.

FIGS. **3**A-**3**C are diagrams of an example implementation described herein.

FIG. **4** is a diagram of example components of one or more devices of FIGS. **1** and **2**.

FIGS. **5** and **6** are flowcharts of example processes relating to adjusting an edge exposure lens.

DETAILED DESCRIPTION

The following disclosure provides many different embodiments, or examples, for implementing different features of the provided subject matter. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

Further, spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are

intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

A wafer edge exposure (WEE) tool may include a vacuum chuck on which a wafer is mounted. A WEE tool may also include a lens that is connected to an electromagnetic radiation source. The lens may be used to focus electromagnetic radiation from the electromagnetic radiation source toward the edge of a wafer. Operation of the WEE tool may cause some operating parameters of the WEE tool to shift or change over time and from cycle to cycle. For example, the vertical and/or horizontal position of the lens may change over time, the lens may become fogged due to repeated exposure cycles, the WEE tool may be used on wafers having different edge thicknesses, and/or the condition of the electromagnetic radiation source may degrade over time and over an accumulation of exposure cycles. As a result, the position of the lens, the focus of the lens, the illuminance of the lens, and/or other parameters may change over repeated cycles of the WEE tool, which can result in the performance of the WEE tool drifting out of tolerance. This may result in reduced operation performance of the WEE tool, and may result in scratches on the surface of a wafer due to improper lens positioning.

Some implementations described herein provide an edge exposure tool (e.g., a WEE tool) that includes a lens adjustment device. The lens adjustment device is capable of automatically adjusting various parameters of an edge exposure lens of the edge exposure tool to account for changes in operating parameters of the edge exposure tool over time and from cycle to cycle. The edge exposure tool may include a controller that is capable of determining one or more edge adjustment parameters for the edge exposure lens and one or more exposure control parameters for the edge exposure tool using techniques such as big data mining, machine learning, and neural network processing. In this way, the lens adjustment device and the controller are capable of reducing and/or preventing the performance of the edge exposure tool from drifting out of tolerance, which can maintain the operation performance of the edge exposure tool and reduce the likelihood of wafer scratching. Moreover, in this way, the lens adjustment device and the controller may reduce the downtime of the edge exposure tool that would otherwise be caused by cleaning and calibration of the edge exposure lens, which increases the productivity and throughput of the edge exposure tool.

FIG. **1** is a diagram of an example edge exposure tool **100** described herein. In some implementations, the edge exposure tool **100** includes a WEE tool. In some implementations, the edge exposure tool **100** is included in another tool such as a photoresist coating tool, a coater/developer tool, or in another type of semiconductor processing tool.

As shown in FIG. **1**, the edge exposure tool **100** may include a vacuum chuck **102** configured to support and secure a wafer **104**. For example, the vacuum chuck **102** may include a platform on which the wafer **104** may be placed and supported, and one or more openings through the platform. A negative pressure may be generated through the openings, which causes a suction force on the bottom surface of the wafer **104**. This suction force pulls the wafer toward the platform and secures the wafer **104** in place. The platform may be sized to accommodate a particular size of

wafer (e.g., a 300 millimeter (mm) wafer) or may be sized to accommodate multiple sizes of wafers (e.g., 200 mm wafers and 300 mm wafers).

The vacuum chuck **102** may be attached to a spindle **106**. The spindle **106** may be configured to spin or rotate the platform of the vacuum chuck **102**. The rotation of the platform of the vacuum chuck **102** may also spin or rotate the wafer **104** on the platform of the vacuum chuck **102**. The spindle **106**, the vacuum chuck **102**, and the wafer **104** may all spin or rotate about a central axis **108** to provide an approximately symmetrical and uniform rotation of the wafer **104**.

The edge exposure tool **100** may include an edge exposure lens **110** configured to direct and/or focus radiation **112** toward a photoresist layer **114** on the wafer **104**. The edge exposure lens **110** may be configured to direct the radiation **112** (e.g., electromagnetic radiation) toward the photoresist layer **114** in an exposure field **116** at or approximately near (e.g., a distance **118** from) an edge of the wafer **104**. In particular, the edge exposure lens **110** may direct and/or focus the radiation **112** toward the wafer **104** when or while the wafer **104** is spun or rotated about the axis **108**. In this way, the radiation **112** may be directed toward the photoresist layer **114** in the exposure field **116** along the circumference of the wafer **104** as the wafer spins or rotates.

The edge exposure tool **100** may include a controller **120**, which may include a microcontroller, a processor, or a device that includes a microcontroller or processor. The controller **120** may be communicatively connected to the vacuum chuck **102**, the spindle **106**, and the edge exposure lens **110**. The controller **120** may receive signals from the vacuum chuck **102**, the spindle **106**, and/or the edge exposure lens **110** (or from sensors associated with the vacuum chuck **102**, the spindle **106**, and/or the edge exposure lens **110**). The received signals may include position information (e.g., position information associated with the edge exposure lens **110**), actuation information (e.g., rotational speed associated with the vacuum chuck **102** and/or the spindle **106**), and/or one or more other types of information. The controller **120** may provide signals to the vacuum chuck **102**, the spindle **106**, and/or the edge exposure lens **110** (or to actuators associated with the vacuum chuck **102**, the spindle **106**, and/or the edge exposure lens **110**). The signals may include digital signals (e.g., communications, instructions, commands, requests, and/or other types of digital signals) and/or analog signals (e.g., voltages, currents, and/or other types of analog signals). The signals may cause the vacuum chuck **102**, the spindle **106**, and/or the edge exposure lens **110** to actuate in a particular manner, such as to spin at a particular rotational velocity or revolutions per minute (RPM), to direct the radiation **112** toward the wafer **104** in a particular exposure field **116** and/or at a particular exposure intensity, or the like.

As indicated above, FIG. **1** is provided as an example. Other examples may differ from what is described with regard to FIG. **1**.

FIG. **2** is a diagram of the example edge exposure tool **100** described herein. FIG. **2** illustrates a detailed view of the edge exposure lens **110**. As shown in FIG. **2**, the edge exposure lens **110** may be mounted to and/or supported by a mounting plate **202** inside of a processing chamber of the edge exposure tool **100**. The mounting plate **202** may include a track, a rail, a guide, or another structure that permits the horizontal position of the edge exposure lens **110** to be adjusted. The horizontal position of the edge exposure lens **110** may be adjusted such that the edge exposure lens **110** (and the resulting exposure field **116**) is moved inward closer toward the center of the wafer **104** or outward closer toward the edge of the wafer **104**. The edge exposure lens **110** may also include a vertical adjustment section **204**, which includes one or more subsections configured to permit the height or vertical position of the edge exposure lens **110** to be adjusted.

The edge exposure lens **110** may include a first section **206** and a second section **208**. The first section **206** and the second section **208** may be adjustable sections of the edge exposure lens **110** in that the height or vertical position of the first section **206** and the second section **208** is permitted to be adjusted. The first section **206** may be interfaced with the vertical adjustment section **204** in a manner that permits the height or vertical position of the first section **206** to be adjusted relative to the height or vertical position of the vertical adjustment section **204**. For example, the first section **206** may be inserted into the vertical adjustment section **204** (or one or more of the subsections included in the vertical adjustment section **204**) such that the first section **206** is permitted to slide internally in the vertical adjustment section **204**. As another example, the first section **206** may be positioned around the vertical adjustment section **204** (or one or more of the subsections included in the vertical adjustment section **204**) such that the vertical adjustment section **204** is inserted into the first section **206**. The vertical adjustment section **204** may be permitted to slide internally in the first section **206** to adjust the height or vertical position of the first section **206**.

The second section **208** may be interfaced with the first section **206** in a manner that permits the height or vertical position of the second section **208** to be adjusted. Moreover, the second section **208** may be interfaced with the first section **206** in a manner that permits the height or vertical position of the second section **208** and the height or vertical position of the first section **206** to be adjusted separately of and/or independently. For example, the second section **208** may be inserted into the first section **206** such that the second section **208** is permitted to slide internally in the first section **206**. As another example, the second section **208** may be positioned around the first section **206** such that the first section **206** is inserted into the second section **208**. The first section **206** may be permitted to slide internally in the second section **208** to adjust the height or vertical position of the second section **208**.

The edge exposure lens **110** may include a lens section **210** attached to and/or supported by the second section **208**. The lens section **210** may include one or more lens elements or lenses. The radiation **112** may travel through the vertical adjustment section **204**, the first section **206**, the second section **208**, and through the lens section **210**. The lens(es) of the lens section **210** may focus or direct the radiation **112** toward the photoresist layer **114** on the wafer **104**.

The height or vertical position of the lens section **210** may be adjusted by adjusting the height or vertical position adjustment of the first section **206** and/or the height or vertical position adjustment of the second section **208**. Adjustments to the height or vertical position of the lens section **210** may change the distance between the lens section **210** and the top surface of the photoresist layer **114**. Adjusting the distance between the lens section **210** and the top surface of the photoresist layer **114** may be one technique for increasing or decreasing the size of the exposure field **116** on the photoresist layer **114**. Additionally or alternatively, the size of the exposure field **116** may be adjusted by increasing or decreasing the size of the aperture through which the radiation **112** travels through the lens section **210** and toward the photoresist layer **114**.

As further shown in FIG. **2**, the edge exposure tool **100** includes a lens adjustment device **212** configured to adjust one or more parameters of the edge exposure lens **110** or one or more components thereof. For example, the lens adjustment device **212** may be configured to adjust the horizontal position of the edge exposure lens **110**, may be configured to adjust the distance between the lens section **210** and the top surface of the wafer **104** (e.g., the top surface of the photoresist layer **114** on the wafer **104**), may be configured to adjust the height or vertical position of the first section **206** and/or the second section **208**, and/or may be configured to adjust one or more other parameters of the edge exposure lens **110**.

The lens adjustment device **212** may include an elongated support member **214** that may be mounted to and/or supported by the mounting plate **202**. In some implementations, the elongated support member **214** is mounted to and/or supported by another structure of the edge exposure tool **100**, such as a table or a wall. The lens adjustment device **212** may include a plurality of lens adjustment elements, including a first lens adjustment element **216** configured to adjust the first section **206**, and a second lens adjustment element **218** configured to adjust the second section **208**.

The first lens adjustment element **216** may include a housing **220***a*, a first support arm **222***a* attached to the housing **220***a* and configured to support the first section **206**. The first support arm **222***a* may be inserted in the housing **220***a* and configured to slide in the housing **220***a* to adjust the horizontal position of the first section **206**. The first lens adjustment element **216** may also include an adjustment motor **224***a* mounted to the housing **220***a*. The adjustment motor **224***a* may be connected to one or more gears, sprockets, and/or other internal components that, together, are configured to adjust the height or vertical position of the first lens adjustment element **216** (and thus, the height or vertical position of the first section **206**). The adjustment motor **224***a* may include a stepper motor, a direct current (DC) motor, or another type of motor. The adjustment motor **224***a* may move the first lens adjustment element **216** along the elongated support member **214**. In particular, the adjustment motor **224***a* may move the first lens adjustment element **216** along a track **226***a* on the elongated support member **214**. The gears and/or sprockets in the housing **220***a* may interface with the track **226***a* to move the first lens adjustment element **216** up and down along the elongated member **214** in a precise and controlled manner.

The controller **120** may provide signals to the adjustment motor **224***a* to cause the adjustment motor **224***a* to operate to adjust the height or vertical position of the first section **206** and/or to adjust the horizontal position of the first section **206** (e.g., by causing the adjustment motor **224***a* to move the first support arm **222***a* inward toward and/or outward from the housing **220***a*). In some implementations, the controller **120** receives signals carrying position information from a position sensor **228***a* mounted to the first support arm **222***a*. The position sensor **228***a* may include a proximity sensor, a Hall effect sensor, a linear variable displacement transducer (LVDT), or another type of sensor that is capable of generating position information. The position information may include information identifying a horizontal position of the first lens adjustment element **216**, which the controller **120** may use to determine the horizontal position of the first section **206**. Moreover, the position information may include information identifying a height or vertical position of the first lens adjustment element **216**, which the controller **120** may use to determine the height or vertical position of the first section **206**.

The second lens adjustment element **218** may include a housing **220***b*, a second support arm **222***b* attached to the housing **220***b* and configured to support the second section **208**. The second support arm **222***b* may be inserted in the housing **220***b* and configured to slide in the housing **220***b* to adjust the horizontal position of the second section **208**. The second lens adjustment element **218** may also include an adjustment motor **224***b* mounted to the housing **220***b*. The adjustment motor **224***b* may be connected to one or more gears, sprockets, and/or other internal components that, together, are configured to adjust the height or vertical position of the second lens adjustment element **218** (and thus, the height or vertical position of the second section **208**). The adjustment motor **224***b* may include a stepper motor, a DC motor, or another type of motor. The adjustment motor **224***b* may move the second lens adjustment element **218** along the elongated support member **214**. In particular, the adjustment motor **224***b* may move the second lens adjustment element **218** along a track **226***b* on the elongated support member **214**. The gears and/or sprockets in the housing **220***b* may interface with the track **226***b* to move the second lens adjustment element **218** up and down along the elongated member **214** in a precise and controlled manner.

The controller **120** may provide signals to the adjustment motor **224***b* to cause the adjustment motor **224***b* to operate to adjust the height or vertical position of the second section **208** and/or to adjust the horizontal position of the second section **208** (e.g., by causing the adjustment motor **224***b* to move the second support arm **222***b* inward toward and/or outward from the housing **220***b*). In some implementations, the controller **120** receives signals carrying position information from a position sensor **228***b* mounted to the second support arm **222***b*. The position sensor **228***b* may include a proximity sensor, a Hall effect sensor, an LVDT, or another type of sensor that is capable of generating position information. The position information may include information identifying a horizontal position of the second lens adjustment element **218**, which the controller **120** may use to determine the horizontal position of the second section **208**. Moreover, the position information may include information identifying a height or vertical position of the second lens adjustment element **218**, which the controller **120** may use to determine the height or vertical position of the second section **208**.

As further shown in FIG. **2**, the edge exposure tool **100** may further include a radiation source **230**. The radiation source **230** may include a deep ultraviolet (UV) radiation source, an extreme UV radiation source, a x-ray radiation source, an electron beam (e-beam) radiation source, or another type of radiation source that is configured to generate and provide a type of radiation that may be used in semiconductor lithography. The radiation source **230** may be connected to the edge exposure lens **110** by a fiber optic cable, and may supply the radiation **112** to the edge exposure lens **110** through the fiber optic cable.

The controller **120** may be communicatively connected with the radiation source **230** to control the radiation source **230**. For example, the controller **120** may initiate operation of the radiation source **230**, may deactivate the radiation source **230**, may control various exposure control parameters of the radiation source **230** described in connection with FIG. **5** herein, and/or may control other operating parameters of the radiation source **230**. The controller **120** may also be communicatively connected with the vacuum chuck **102** to control various parameters of the vacuum chuck **102** described in connection with FIG. **5** herein.

As indicated above, FIG. **2** is provided as an example. Other examples may differ from what is described with regard to FIG. **2**.

FIGS. **3A-3C** are diagrams of an example implementation **300** described herein. In some implementations, the example implementation **300** includes one or more examples of adjusting the edge exposure lens **110** using the lens adjustment device **212**. In some implementations, the lens adjustment device **212** adjusts the edge exposure lens **110** between exposure cycles of the edge exposure tool **100** to account for cycle-to-cycle changes and variation in the edge exposure tool. In some implementations, the lens adjustment device **212** may adjust the edge exposure lens **110** based on maintenance or repairs being performed on the edge exposure lens **110**. For example, the lens adjustment device **212** may adjust the edge exposure lens **110** based on the edge exposure lens **110** being disassembled to replace the lens section **210**. As an example, the lens adjustment device **212** may adjust the edge exposure lens **110** after the first section **206** and the second section **208** are removed from the edge exposure lens **110** and separated such that a lens element of the lens section **210** may be removed and cleaned or replaced. The lens element (or a new lens element) may be installed in the lens section **210**, and the first section **206** and the second section **208** may be joined after cleaning or replacement of the lens element. The first section **206** and the second section **208** may be installed back into the edge exposure lens **110**, and the techniques described in connection with FIGS. **3A-3C** (and in connection with FIG. **5** herein) may be performed to adjust the edge exposure lens **110** (or one or more components thereof) using the lens adjustment device **212**.

As shown in FIG. **3A**, and by reference number **302**, the controller **120** may determine one or more edge exposure lens adjustment parameters for adjusting the position of the edge exposure lens **110** or positions of one or more components of the edge exposure lens **110**. The one or more edge exposure lens adjustment parameters for adjusting the position of the edge exposure lens **110** or positions of one or more components of the edge exposure lens **110** from an initial position (or initial positions) to a target position (or target positions). The controller **120** may determine the target position (or target positions), as described in connection with FIG. **5** herein, to achieve a particular performance of the edge exposure lens **110** and/or the edge exposure tool **100**, such as an exposure uniformity parameter, an exposure field size, an overlay alignment parameter (e.g., an interlayer alignment between various layers formed on the wafer **104**), and/or one or more other performance parameters. Additionally or alternatively, the controller **120** may determine the target position (or target positions) based on a size of the wafer **104** to be exposed, based on a pattern to be transferred to the wafer **104**, based on a thickness of the wafer **104**, based on a thickness of the photoresist layer **114**, and/or based on one or more other parameters.

As shown in FIG. **3B**, and by reference number **304**, the controller **120** may automatically cause one or more parameters of the edge exposure lens **110** to be adjusted based on the one or more edge exposure lens adjustment parameters. For example, the controller **120** may provide a signal to the lens adjustment device **212** to cause the lens adjustment device **212** to adjust a height or vertical position **306** of the first section **206** based on determining the one or more edge exposure lens adjustment parameters. The controller **120** may receive position information from the position sensor **228*a*** indicating the initial height or vertical position of the first section **206**, may provide the signal to the lens adjustment device **212** to activate the adjustment motor **224*a*** to cause the adjustment motor **224*a*** to move the first lens adjustment element **216** (which causes the first section **206** to move from the initial height or vertical position) based on the one or more edge exposure lens adjustment parameters. The controller **120** may continue to receive the position information from the position sensor **228*a***, and may determine that the first section **206** has reached a target height or vertical position based on the position information. The controller **120** may provide a signal to the lens adjustment device **212** (or may cease providing the signal to the lens adjustment device **212**) to deactivate the adjustment motor **224*a*** based on determining that the first section **206** is at the target height or vertical position.

As another example, the controller **120** may provide a signal to the lens adjustment device **212** to cause the lens adjustment device **212** to adjust a height or vertical position **308** of the second section **208**. The controller **120** may receive position information from the position sensor **228*b*** indicating the initial height or vertical position of the second section **208**, may provide the signal to the lens adjustment device **212** to activate the adjustment motor **224*b*** to cause the adjustment motor **224*b*** to move the second lens adjustment element **218** (which causes the second section **208** to move from the initial height or vertical position) based on the one or more edge exposure lens adjustment parameters. The controller **120** may continue to receive the position information from the position sensor **228*b***, and may determine that the second section **208** has reached a target height or vertical position based on the position information. The controller **120** may provide a signal to the lens adjustment device **212** (or may cease providing the signal to the lens adjustment device **212**) to deactivate the adjustment motor **224*b*** based on determining that the second section **208** is at the target height or vertical position.

As another example, the controller **120** may provide one or more signals to the lens adjustment device **212** to cause the lens adjustment device **212** to adjust a distance **310** between the lens section **210** of the edge exposure lens **110** and a top surface of the photoresist layer **114** on the wafer **104**. In some implementations, the controller **120** may cause the first lens adjustment element **216** to adjust the height or vertical position **306** of the first section **206** in order to adjust the distance **310**. In some implementations, the controller **120** may cause the second lens adjustment element **218** to adjust the height or vertical position **308** of the second section **208** in order to adjust the distance **310**. In some implementations, the controller **120** may cause the first lens adjustment element **216** to adjust the height or vertical position **306** of the first section **206** and the second lens adjustment element **218** to adjust the height or vertical position **308** of the second section **208** in order to adjust the distance **310**.

As another example, the controller **120** may provide one or more signals to the lens adjustment device **212** to cause the lens adjustment device **212** to adjust a horizontal position **312** of the edge exposure lens **110**. The controller **120** may receive position information from the position sensor **228*a*** and/or the position sensor **228*b*** indicating the initial horizontal position of the first section **206** and the second section **208**, respectively. The controller **120** may provide the one or more signals to the lens adjustment device **212** to activate the adjustment motor **224*a*** and/or the adjustment motor **224*b*** to move the first support arm **222*a*** and the second support arm **222*b*** inward or outward based on the one or more edge exposure lens adjustment parameters to adjust the horizontal position **312**. The controller **120** may

continue to receive the position information from the position sensor **228***a* and/or the position sensor **228***b*, and may determine that the first section **206** and the second section **208** have reached a target horizontal position based on the position information. The controller **120** may provide a signal to the lens adjustment device **212** (or may cease providing the signal to the lens adjustment device **212**) to deactivate the adjustment motor **224***a* and the adjustment motor **224***b* based on determining that the first section **206** and the second section **208** are at the target horizontal position.

Additionally or alternatively to causing the one or more parameters of the edge exposure lens to be adjusted, the controller **120** may cause one or more exposure control parameters of the edge exposure tool **100** to be adjusted. For example, the controller **120** may communicate with and/or provide signals to the vacuum chuck **102**, the edge exposure lens **110**, and/or the radiation source **230** to cause one or more exposure control parameters of the edge exposure tool **100** to be adjusted as described in connection with FIG. **5** herein.

As shown in FIG. **3**C, and by reference number **314**, the controller **120** may cause the edge exposure lens **110** to direct the radiation **112** at or approximately near the edge of the wafer **104** after the one or more parameters of the edge exposure lens **110** are adjusted (and/or after other parameters of the edge exposure tool **100** are adjusted). For example, the controller **120** may provide a signal to the radiation source **230** to activate the radiation source **230** and to cause the radiation source to provide the radiation **112** to the edge exposure lens **110** through the fiber optic cable. The radiation **112** may travel along the fiber optic cable to the edge exposure lens **110**, and may travel through the lens section **210** of the edge exposure lens **110**, which directs the radiation **112** toward the photoresist layer **114** on the wafer **104** in an exposure field **116** a distance **118** from the edge of the wafer **104**.

As indicated above, FIGS. **3**A-**3**C are provided as one or more examples. Other examples may differ from what is described with regard to FIGS. **3**A-**3**C.

FIG. **4** is a diagram of example components of a device **400**, which may correspond to the controller **120**, the adjustment motor **224***a*, the adjustment motor **224***b*, the position sensor **228***a*, the position sensor **228***b*, and/or the radiation source **230**. In some implementations, the controller **120**, the adjustment motor **224***a*, the adjustment motor **224***b*, the position sensor **228***a*, the position sensor **228***b*, and/or the radiation source **230** may include one or more devices **400** and/or one or more components of device **400**. As shown in FIG. **4**, device **400** may include a bus **410**, a processor **420**, a memory **430**, a storage component **440**, an input component **450**, an output component **460**, and a communication component **470**.

Bus **410** includes a component that enables wired and/or wireless communication among the components of device **400**. Processor **420** includes a central processing unit, a graphics processing unit, a microprocessor, a controller, a microcontroller, a digital signal processor, a field-programmable gate array, an application-specific integrated circuit, and/or another type of processing component. Processor **420** is implemented in hardware, firmware, or a combination of hardware and software. In some implementations, processor **420** includes one or more processors capable of being programmed to perform a function. Memory **430** includes a random access memory, a read only memory, and/or another type of memory (e.g., a flash memory, a magnetic memory, and/or an optical memory).

Storage component **440** stores information and/or software related to the operation of device **400**. For example, storage component **440** may include a hard disk drive, a magnetic disk drive, an optical disk drive, a solid state disk drive, a compact disc, a digital versatile disc, and/or another type of non-transitory computer-readable medium. Input component **450** enables device **400** to receive input, such as user input and/or sensed inputs. For example, input component **450** may include a touch screen, a keyboard, a keypad, a mouse, a button, a microphone, a switch, a sensor, a global positioning system component, an accelerometer, a gyroscope, and/or an actuator. Output component **460** enables device **400** to provide output, such as via a display, a speaker, and/or one or more light-emitting diodes. Communication component **470** enables device **400** to communicate with other devices, such as via a wired connection and/or a wireless connection. For example, communication component **470** may include a receiver, a transmitter, a transceiver, a modem, a network interface card, and/or an antenna.

Device **400** may perform one or more processes described herein. For example, a non-transitory computer-readable medium (e.g., memory **430** and/or storage component **440**) may store a set of instructions (e.g., one or more instructions, code, software code, and/or program code) for execution by processor **420**. Processor **420** may execute the set of instructions to perform one or more processes described herein. In some implementations, execution of the set of instructions, by one or more processors **420**, causes the one or more processors **420** and/or the device **400** to perform one or more processes described herein. In some implementations, hardwired circuitry may be used instead of or in combination with the instructions to perform one or more processes described herein. Thus, implementations described herein are not limited to any specific combination of hardware circuitry and software.

The number and arrangement of components shown in FIG. **4** are provided as an example. Device **400** may include additional components, fewer components, different components, or differently arranged components than those shown in FIG. **4**. Additionally, or alternatively, a set of components (e.g., one or more components) of device **400** may perform one or more functions described as being performed by another set of components of device **400**.

FIG. **5** is a flowchart of an example process **500** associated with adjusting an edge exposure lens. In some implementations, one or more process blocks of FIG. **5** may be performed by a controller (e.g., the controller **120**, the device **400**). In some implementations, one or more process blocks of FIG. **5** may be performed by another device or a group of devices separate from or including the controller, such as lens adjustment device (e.g., lens adjustment device **212**), a radiation source (e.g., the radiation source **230**), and/or another device. Additionally, or alternatively, one or more process blocks of FIG. **5** may be performed by one or more components of device **400**, such as processor **420**, memory **430**, storage component **440**, input component **450**, output component **460**, and/or communication component **470**.

As shown in FIG. **5**, process **500** may include adjusting a position of the edge exposure lens **110** included in the edge exposure tool **100** and adjusting an exposure control for the edge exposure tool **100** (block **510**). For example, the controller **120** may determine one or more edge exposure lens adjustment parameters for adjusting the position of the edge exposure lens **110**, and may determine one or more exposure adjustment parameters for adjusting the exposure control for the edge exposure tool **100**.

Process **500** may include a plurality of operations for determining the adjustment parameters (e.g., the one or more edge exposure lens adjustment parameters and the one or more exposure adjustment parameters). As shown in FIG. **5**, process **500** may include determining one or more cycle-to-cycle tuning parameters for the edge exposure tool **100** (block **520**). For example, the controller **120** may determine the one or more cycle-to-cycle tuning parameters. The cycle-to-cycle tuning parameters may include parameters of the edge exposure tool **100** that may change from exposure cycle to exposure cycle. An exposure cycle may include one exposure operation on a wafer **104** performed by the edge exposure tool **100**. For example, an exposure cycle may include placing the wafer **104** on the vacuum chuck **102**, spinning or rotating the vacuum chuck **102** to spin/rotate the wafer **104**, and exposing the photoresist layer **114** on the wafer **104** to the radiation **112** for one or more revolutions or complete rotations of the wafer **104**.

As further shown in FIG. **5**, in some implementations, the one or more cycle-to-cycle tuning parameters include a lens life of the edge exposure lens **110** (e.g., a quantity of hours or exposure cycles of use of the lens section **210** installed in the edge exposure lens **110**). In some implementations, the one or more cycle-to-cycle tuning parameters include a photoresist life. The photoresist life may refer to how long the raw material of the photoresist layer **114** was stored in a storage tank prior to being deposited on the wafer **104**. In some implementations, the one or more cycle-to-cycle tuning parameters include a lens shutter life. The edge exposure lens **110** may include one or more shutters that open and close at various times and/or at various periodicities. The shutter may be used to expose portions of the photoresist layer **114** to the radiation source **230** when the shutter is open, and to prevent exposure to other portions of the photoresist layer **114** when the shutter is closed. The shutter may also be used to control the total exposure time of a particular portion of the photoresist layer **114**. In some implementations, the one or more cycle-to-cycle tuning parameters include an exposure mode, which may include a round exposure mode (e.g., an exposure mode in which round areas of the wafer **104** are exposed), a linear exposure mode (e.g., an exposure mode in which straight or rectangular areas of the wafer **104** are exposed, such as wafer notch areas), and/or another exposure mode.

In some implementations, the one or more cycle-to-cycle tuning parameters include a vacuum chuck filter life (e.g., a quantity of hours or exposure cycles of use accumulated for the filter installed in the vacuum chuck **102**). In some implementations, the one or more cycle-to-cycle tuning parameters include a lens optical fiber life (e.g., a quantity of hours or exposure cycles of use accumulated for the optical fiber cable through which the radiation **112** is supplied to the edge exposure lens **110** from the radiation source **230**. In some implementations, the one or more cycle-to-cycle tuning parameters include a lens lamp life (e.g., a quantity of hours or exposure cycles of use accumulated for the radiation lamp installed in the radiation source **230**). In some implementations, the one or more cycle-to-cycle tuning parameters include a leveling status of the vacuum chuck **102** (e.g., whether the vacuum chuck **102** is level, out of level, and/or an amount and direction in which the vacuum chuck **102** is out of level).

In some implementations, the one or more cycle-to-cycle tuning parameters include a position shift status of the vacuum chuck **102** (e.g., an amount and direction of a horizontal shift of the vacuum chuck **102** and/or an amount and direction of a vertical shift of the vacuum chuck **102**). In some implementations, the one or more cycle-to-cycle tuning parameters include an exposure distance to the edge of the wafer **104**, which may indicate a distance **118** between the edge of the wafer **104** and the exposure field **116**. In some implementations, the one or more cycle-to-cycle tuning parameters include an exposure rotation life of the edge exposure tool **100** (e.g., a quantity of hours or exposure cycles for the overall edge exposure tool **100**).

In some implementations, the one or more cycle-to-cycle tuning parameters include other parameters. In some implementations, the one or more cycle-to-cycle tuning parameters include a combination of the parameters described above and/or one or more other parameters.

As further shown in FIG. **5**, process **500** may include determining one or more target edge exposure lens parameters and one or more exposure control parameters based on the one or more cycle-to-cycle tuning parameters (block **530**). For example, the controller **120** may determine the one or more target edge exposure lens parameters and the one or more exposure control parameters based on the one or more cycle-to-cycle tuning parameters. The one or more target edge exposure lens parameters and the one or more exposure parameters may include parameters that are determined to achieve a particular performance of the edge exposure lens **110** and/or the edge exposure tool **100**, such as an exposure uniformity parameter, an exposure field size, an overlay alignment parameter (e.g., an interlayer alignment between various layers formed on the wafer **104**), and/or one or more other performance parameters. Additionally or alternatively, the controller **120** may determine the one or more target edge exposure lens parameters and/or the one or more exposure control parameters based on a size of the wafer **104** to be exposed, based on a pattern to be transferred to the wafer **104**, based on a thickness of the wafer **104**, based on a thickness of the photoresist layer **114**, and/or based on one or more other parameters.

In some implementations, the one or more target edge exposure lens parameters include a target horizontal position for the edge exposure lens **110**. For example, the controller **120** may determine target horizontal position based on the horizontal shift of the vacuum chuck **102**, based on a leveling status of the vacuum chuck **102**, and/or one or more other parameters. In some implementations, the controller **120** may determine a target angle of the edge exposure lens **110** (e.g., an angle of the edge exposure lens **110** relative to the planar surface of the platform of the vacuum chuck **102**) based on the leveling status of the vacuum chuck **102**. In these examples, the controller **120** may determine the target horizontal position and the target angle to account for and/or accommodate horizontal shifting of the vacuum chuck **102** over time and/or over a plurality of exposure cycles.

In some implementations, the one or more target edge exposure lens parameters include a target distance parameter for the edge exposure lens **110**. For example, the controller **120** may determine the target distance parameter between lens section **210** and the top surface of the photoresist layer **114** on the wafer **104**. The controller **120** may determine the target distance parameter based on the exposure field of the edge exposure lens **110**, based on a thickness of the wafer **104**, based on a thickness of the photoresist layer **114**, and/or based on one or more other parameters. For example, the controller **120** may determine the target distance parameter such that the exposure field is achieved for the thickness of the wafer **104** and the thickness of the photoresist layer **114**.

In some implementations, the one or more target edge exposure lens parameters include a target vertical position for the first section **206** and/or a target vertical position for

the second section **208** of the edge exposure lens **110**. The controller **120** may determine target vertical position for the first section **206** and/or a target vertical position for the second section **208** based on the vertical shift of the vacuum chuck **102**, based on a leveling status of the vacuum chuck **102**, and/or other parameters. In some implementations, the controller **120** determines the target vertical position for the first section **206** and/or the target vertical position for the second section **208** further based on the target distance parameter between lens section **210** and the top surface of the photoresist layer **114** on the wafer **104**. In these examples, the controller **120** may determine the target vertical position for the first section **206** and/or the target vertical position for the second section **208** to account for vertical shifting of the vacuum chuck **102** over time and/or over a plurality of exposure cycles to achieve the target distance parameter.

In some implementations, the one or more target exposure control parameters a target exposure field size for the exposure field **116** of the edge exposure lens. As an example, the controller **120** may determine the target exposure field size based on the size of the pattern to be transferred to the wafer **104**, based on the size of the wafer **104**, and/or based on one or more other parameters.

In some implementations, the one or more target exposure control parameters may include a target exposure intensity for the radiation **112** that is to be directed toward the photoresist layer **114**. For example, the controller **120** may increase the target exposure intensity as the lifetime of the lens section **210** increases (e.g., as indicated by the lens life included in the one or more cycle-to-cycle tuning parameters) and/or may decrease the target exposure intensity based on the lens section **210** being replaced, cleaned, or serviced. In this way, the controller **120** may adjust the target exposure intensity of the edge exposure lens **110** to stabilize the illuminance of the lens section **210** and to account for fogging of the lens section **210** over time, which may otherwise cause a drop in exposure intensity. Additionally or alternatively, the controller **120** may increase the target radiation based on an increased lens optical fiber life and/or an increased lamp life (e.g., as indicated by the lens life included in the one or more cycle-to-cycle tuning parameters).

In some implementations, the one or more target exposure control parameters may include a target rotation duration. The target rotation duration may include, for example, a time duration (e.g., seconds, minutes) or a quantity of rotations of the wafer **104**. For example, the controller **120** may increase the exposure rotation time of the wafer **104** for a relatively thicker photoresist layer **114**, may decrease the exposure rotation time of the wafer **104** for a relatively thinner photoresist layer **114**, and/or may increase or decrease the exposure rotation time of the wafer **104** to account for photoresist life of the photoresist layer **114** (e.g., as indicated by the lens life included in the one or more cycle-to-cycle tuning parameters). As another example, the controller **120** may increase the exposure rotation time to provide a longer exposure time based on an estimated decrease in exposure intensity resulting from an increased lens life, an increased lens optical fiber life, and/or an increased lamp life (e.g., as indicated by the lens life included in the one or more cycle-to-cycle tuning parameters).

In some implementations, the one or more target exposure control parameters may include a target shutter opening delay for the shutter of the edge exposure lens **110** and/or the one or more target exposure control parameters may include shutter closing delay for the shutter of the edge exposure lens **110**. For example, the controller **120** may determine to increase or decrease the shutter opening delay based on an estimated signal propagation delay between the controller **120** and the edge exposure lens **110** to synchronize the exposure of the wafer **104** to an exposure plan. For example, the controller **120** may increase the target shutter opening delay and/or may increase the target shutter closing delay for higher estimated propagation delay. As another example, the controller **120** may decrease the target shutter opening delay and/or may decrease the target shutter closing delay for lower estimated propagation delay. Additionally or alternatively, the controller **120** may determine the target shutter opening delay and/or the target shutter closing delay based on an exposure mode for the wafer **104** to be exposed.

In some implementations, the controller **120** determines the one or more target edge exposure lens parameters and/or the one or more target exposure control parameters using various data processing techniques, such as big data mining, machine learning, and/or neural network processing. In some implementations, the controller **120** uses big data mining to collect and store cycle-to-cycle tuning parameter data from thousands (or more) of exposure cycles of the edge exposure tool **100** or an edge exposure tool similar to the edge exposure tool **100** (e.g., an edge exposure tool that is a same make and model as the edge exposure tool **100**, an edge exposure tool that has common characteristics as the edge exposure tool **100**, or the like). In these examples, the controller **120** may obtain the cycle-to-cycle tuning parameter data from various sensors and/or actuators of the edge exposure tool **100**, may receive the cycle-to-cycle tuning parameter data as input from an operator, and/or may receive the cycle-to-cycle tuning parameter data from one or more other sources. The controller **120** may store the cycle-to-cycle tuning parameter data in a database or data store, and may structure the cycle-to-cycle tuning parameter data (e.g., if received as unstructured data) using various data structuring techniques (e.g., tagging, generating metadata, categorizing, and/or one or more other techniques). Moreover, the controller **120** may use big data mining to collect and store exposure control parameters and/or edge exposure lens parameters that were used for the multiple thousands of exposure cycles of the edge exposure tool **100**, and may collect and store performance data from the multiple thousands of exposure cycles of the edge exposure tool **100** in a similar manner. The database or data store may be continuously and/or periodically updated as data from subsequent exposures becomes available.

In some implementations, the controller **120** uses machine learning and/or neural network processing for decision making when determining the one or more target edge exposure lens parameters and/or the one or more target exposure control parameters. Machine learning involves computers learning from data to perform tasks and/or to make decisions. Machine learning algorithms are used to train machine learning models based on sample data, known as "training data." Once trained, machine learning models may be used to make predictions, decisions, or classifications relating to new observations. Here, the controller **120** may train a machine learning model on the cycle-to-cycle tuning parameter data, the exposure control parameters, the edge exposure lens parameters, and/or the performance data from thousands (or more) of exposure cycles of the edge exposure tool **100**. Alternatively, a separate device (e.g., a server device) may train the machine learning model and may provide the trained machine learning model for use by the controller **120**.

The machine learning model may be trained on the data from thousands (or more) of exposure cycles using a supervised learning technique and/or an unsupervised learning technique. In some implementations, the controller **120** trains a regression model, a decision tree model, a Naïve Bayes classifier, a k nearest neighbor (KNN) model, or another type of supervised machine learning model by specifying a target or outcome variable that is to be predicted from an independent set of variables. In some implementations, the controller **120** uses a neural network (e.g., an artificial neural network that includes thousands or millions (or more) of artificial neurons or processing nodes) to train the machine learning model using a deep learning technique. The nodes in the neural network may be layered and weighted. A node in a layer of the neural network may be connected to a plurality of nodes in a lower layer of the neural network, and may receive a weight from each of the nodes in the lower layer. The node may update the weights and feed forward a weight to one or more nodes in a higher layer in the neural network if the weight satisfies a threshold (which may be referred to as a "firing" of the node). The weights in the neural network may be adjusted and/or updated as the neural network continues to process the training data provided to the machine learning model until similar training data parameters yield similar weights through the neural network.

The machine learning model may generate a function that maps inputs to the machine learning model (e.g., the cycle-to-cycle tuning parameter data, the exposure control parameters, the edge exposure lens parameters, the performance data, and/or one or more initial parameters for the edge exposure tool **100**) to specified outputs from the machine learning model (e.g., one or more specified performance parameters of the edge exposure tool **100**). In this way, the controller **120** uses the function (e.g., determined by the machine learning model) to determine the one or more target edge exposure lens parameters and/or the one or more target exposure control parameters that may be used to achieve a specified performance of the edge exposure lens **110** and/or the edge exposure tool **100**, such as a specified exposure uniformity, a specified exposure field size, a specified overlay alignment, and/or one or more other specified performance parameters.

As further shown in FIG. **5**, process **500** may include determining one or more edge exposure lens adjustment parameters (block **540**). For example, the controller **120** may determine the one or more edge exposure lens adjustment parameters based on the one or more target edge exposure lens parameters and one or more initial edge exposure lens parameters for the edge exposure lens **110**. The one or more initial edge exposure lens parameters may include an initial position (e.g., horizontal position, vertical position, exposure angle, distance from the wafer **104**, or the like), may include a starting position (e.g., after powering on the edge exposure tool **100**), or another type of initial position. The controller **120** may receive position information from the position sensors **228***a* and **22***b*, which may indicate the initial position of the edge exposure lens **110**, the initial position of the first section **206**, the initial position of the second section **208**, the initial position of the lens section **210**, and/or one or more other initial positions of the edge exposure lens **110**.

The one or more edge exposure lens adjustment parameters may include parameters to adjust the edge exposure lens **110** from the initial position to the target position determined by the controller **120**. For example, a vertical position parameter for the first section **206** may include a parameter that identifies an amount of displacement for moving the first section **206** from the initial position of the first section **206** to the target vertical position of the first section **206**.

In some implementations, the controller **120** determines other adjustment parameters for the edge exposure tool **100**. For example, the controller **120** may determine a vacuum intensity adjustment parameter for the vacuum chuck **102**. In these examples, the vacuum performance for a particular vacuum intensity setting for the vacuum chuck **102** may decrease over time and over a plurality of exposure cycles as the vacuum filter of the vacuum chuck **102** filters dust and debris from the vacuum lines of the vacuum chuck **102**. The increased amount of dust and debris captured by the vacuum filter may decrease the airflow through the vacuum filter, thereby decreasing the vacuum performance of the vacuum chuck **102**. Accordingly, the controller **120** may determine the vacuum intensity adjustment parameter to increase the vacuum intensity of the vacuum chuck **102** as the vacuum filter life of the vacuum filter increases to maintain a particular vacuum performance. Additionally or alternatively, the controller **120** may determine the vacuum intensity adjustment parameter to account for difference sized wafers. For example, the controller **120** may increase the vacuum intensity for larger wafers (e.g., 300 mm wafers) and may decrease the vacuum intensity for smaller wafers (e.g., 150 mm wafers, 200 mm wafers).

Referring back to block **510**, the controller **120** may adjust the position (e.g., the initial position) of the edge exposure lens **110** based on the one or more edge exposure adjustment parameters. In some implementations, the controller **120** causes the lens adjustment device **212** to adjust the vertical position **306** of the first section **206** of the edge exposure lens **110**. For example, the controller **120** may provide a signal to the adjustment motor **224***a* to cause the adjustment motor **224***a* to move the first section **206** up or down based on a vertical position adjustment parameter for the first section **206** to a target vertical position. In some implementations, the controller **120** causes the lens adjustment device **212** to adjust the vertical position **308** of the second section **208** of the edge exposure lens **110** by providing a signal to the adjustment motor **224***b* to cause the adjustment motor **224***b* to move the second section **208** up or down based on a vertical position adjustment parameter for the first section **206** to a target vertical position.

In some implementations, the controller **120** causes the lens adjustment device **212** to adjust the distance **310** between the top surface of the wafer **104** (e.g., the top surface of the photoresist layer **114** on the wafer **104**) and the edge exposure lens **110** (e.g., the lens section **210** of the edge exposure lens **110**) based on a distance adjustment parameter to a target distance. Adjusting the distance **310** may include adjusting the vertical position **306** of the first section **206** of the edge exposure lens **110**, adjusting the vertical position **308** of the second section **208** of the edge exposure lens **110**, or a combination thereof.

In some implementations, the controller **120** causes the lens adjustment device **212** to adjust a horizontal position of the edge exposure lens **110** in one or more directions based on a horizontal position adjustment parameter. For example, the controller **120** may provide a signal to the adjustment motor **224***a* and the adjustment motor **224***b* to respectively cause the first support arm **222***a* and the second support arm **222***b* to move inward toward the elongated support member **214**, outward from the elongated support member **214**, and/or to rotate about the elongated support member **214** to adjust the horizontal position of the edge exposure lens **110**

to a target horizontal position. The adjustment of the horizontal position of the edge exposure lens **110** may change the distance **118** between the exposure field **116** and the edge of the wafer **104**.

In some implementations, the controller **120** causes the lens adjustment device **212** to adjust an angle of the edge exposure lens **110** (e.g., an angle of the edge exposure lens **110** relative to the planar surface of the wafer **104**). For example, the controller **120** may provide a signal to the adjustment motor **224***a* and/or the adjustment motor **224***b* to respectively cause the first support arm **222***a* and/or the second support arm **222***b* to move inward toward the elongated support member **214**, outward from the elongated support member **214**, and/or to rotate about the elongated support member **214** to adjust the angle of the edge exposure lens **110**.

The controller **120** may adjust the exposure control for the edge exposure tool **100** based on the one or more exposure control parameters. In some implementations, the controller **120** causes the edge exposure lens **110** to adjust the exposure field **116** of the edge exposure lens **110** based on an exposure field exposure control parameter to a target exposure field size. As an example, the controller **120** may provide a signal to the edge exposure lens **110** to increase or decrease an aperture through which the radiation **112** is permitted to travel through the lens section **210**. Increasing the aperture may increase the size of the exposure field **116**, whereas decreasing the aperture may decrease the size of the exposure field **116**.

In some implementations, the controller **120** causes the radiation source **230** to increase and/or decrease the exposure intensity of the radiation **112** based on the exposure intensity. For example, the controller **120** may provide a signal to the edge exposure lens **110** to increase and/or decrease the exposure intensity of the radiation **112**. In some implementations, the controller **120** causes the radiation source **230** to adjust a lower exposure intensity or a minimum exposure control of the radiation **112** and a reference exposure intensity or reference exposure control. In some implementations, the controller **120** causes the radiation source **230** to adjust the lower exposure intensity and/or the reference exposure intensity to achieve a particular reference exposure intensity range, such as approximately 260 milliwatts per centimeters squared (mW/cm^2) to approximately 280 mW/cm^2, approximately 260 mW/cm^2 to approximately 300 mW/cm^2, or another example range.

In some implementations, the controller **120** adjusts the exposure rotation time for the wafer **104** based on an exposure duration exposure control parameter to achieve a target rotation duration. The target rotation duration may include, for example, a time duration (e.g., seconds, minutes) or a quantity of rotations of the wafer **104**. For example, the controller **120** may adjust the exposure rotation time of the wafer **104** to 6 rotations, 20 rotations, 22 rotations, 40 rotations, or another quantity of rotations.

In some implementations, the controller **120** causes the edge exposure lens to increase or decrease a shutter opening delay for the shutter of the edge exposure lens **110** and/or a shutter closing delay for the shutter of the edge exposure lens **110**. For example, the controller **120** may provide a signal to the edge exposure lens **110** to increase or decrease the shutter opening delay based on a shutter opening delay exposure control parameter to a target shutter opening delay (e.g., 0.1 seconds, 0.2 seconds, or another shutter opening delay). As another example, the controller **120** may provide a signal to the edge exposure lens **110** to increase or decrease the shutter closing delay based on a shutter closing delay exposure control parameter to a target shutter closing delay (e.g., 0.1 seconds, 0.2 seconds, or another shutter closing delay). The exposure opening delay may be a time duration between the edge exposure lens **110** receiving a signal (e.g., from the controller **120**) to open the shutter of the edge exposure lens **110** and the time that the edge exposure lens **110** actually opens the shutter. The exposure closing delay may be a time duration between the edge exposure lens **110** receiving a signal (e.g., from the controller **120**) to close the shutter of the edge exposure lens **110** and the time that the edge exposure lens **110** actually closes the shutter. The shutter opening delay and the shutter closing delay can be used to compensate for signal propagation delays between the controller **120** and the edge exposure lens **110** to synchronize the exposure of the wafer **104** to an exposure plan.

In some implementations, the controller **120** adjusts one or more other parameters of the edge exposure tool **100**. For example, the controller **120** may cause the vacuum chuck **102** to increase or decrease a vacuum intensity of the vacuum chuck **102** based on the vacuum intensity adjustment parameter.

While a plurality of different parameters of the edge exposure tool **100** has been described above, these parameters are simply examples of parameters that might be used. In practice, any single parameter described above or any combination of the parameters described above may be used.

As shown in FIG. **5**, process **500** may include exposing the wafer **104** at or approximately near the edge of the wafer **104** to radiation for an exposure cycle before, during, and/or after adjusting the edge exposure lens **110** and before, during, and/or after adjusting the one or more edge exposure adjustment parameters (block **550**). The controller **120** may cause the edge exposure tool **100** to expose the wafer **104** by providing a signal to the radiation source **230** to cause the radiation source **230** to emit the radiation **112**.

The controller **120** may further cause the edge exposure tool **100** to expose the wafer **104** by providing a signal to the edge exposure lens **110** to open and close a shutter of the edge exposure lens **110** (e.g., to control which portions of the photoresist layer **114** are exposed and a duration of exposure for the portions). The controller **120** may further provide a signal to the spindle **106** of the vacuum chuck **102** to cause the spindle **106** to spin or rotate the wafer **104** when the wafer **104** is exposed to the radiation **112**. The controller **120** may further provide a signal to the vacuum chuck **102** to cause the vacuum chuck **102** to generate a vacuum or suction force on the wafer **104** to hold the wafer against the vacuum chuck **102** when the wafer is rotated by the spindle **106**.

After completion of the exposure cycle, results of the exposure cycle may be incorporated into the big data database, the machine learning model, and/or the neural network to further refine adjustment parameter determination and exposure control parameter determination for subsequent exposure cycles. In particular, the results (e.g., exposure uniformity information, overlay alignment information, and/or one or more other performance information) and the associated parameters (e.g., edge exposure lens adjustment parameters and/or exposure control parameters) may be used as further training data on which the machine learning model and/or the neural network may be trained to further refine the machine learning model and/or the neural network.

Process **500** may include additional implementations, such as any single implementation or any combination of implementations described above, below, and/or in connection with one or more other processes described elsewhere herein.

Although FIG. **5** shows example blocks of process **500**, in some implementations, process **500** may include additional blocks, fewer blocks, different blocks, or differently arranged blocks than those depicted in FIG. **5**. Additionally, or alternatively, two or more of the blocks of process **500** may be performed in parallel.

FIG. **6** is a flowchart of an example process **600** associated with adjusting an edge exposure lens. In some implementations, one or more process blocks of FIG. **6** may be performed by a controller (e.g., the controller **120**, the device **400**). In some implementations, one or more process blocks of FIG. **6** may be performed by another device or a group of devices separate from or including the controller, such as lens adjustment device (e.g., lens adjustment device **212**), a radiation source (e.g., the radiation source **230**), and/or another device. Additionally, or alternatively, one or more process blocks of FIG. **6** may be performed by one or more components of device **400**, such as processor **420**, memory **430**, storage component **440**, input component **450**, output component **460**, and/or communication component **470**.

As shown in FIG. **6**, process **600** may include determining one or more edge exposure lens adjustment parameters for an edge exposure lens of an edge exposure tool (block **610**). For example, the controller may determine one or more edge exposure lens adjustment parameters for an edge exposure lens **110** of the edge exposure tool **100**, as described above.

As further shown in FIG. **6**, process **600** may include causing a lens adjustment device of the edge exposure tool to adjust one or more parameters of the edge exposure lens based on the one or more edge exposure lens adjustment parameters (block **620**). For example, the controller may cause a lens adjustment device **212** of the edge exposure tool **100** to adjust one or more parameters of the edge exposure lens **110** based on the one or more edge exposure lens adjustment parameters, as described above.

As further shown in FIG. **6**, process **600** may include causing the edge exposure lens to direct radiation toward a wafer at or approximately near an edge of the wafer after the one or more parameters of the edge exposure lens are adjusted (block **630**). For example, the controller may cause the edge exposure lens to direct the radiation **112** toward the wafer **104** at or approximately near an edge of the wafer **104** after the one or more parameters of the edge exposure lens **110** are adjusted, as described above.

Process **600** may include additional implementations, such as any single implementation or any combination of implementations described below and/or in connection with one or more other processes described elsewhere herein.

In a first implementation, causing the lens adjustment device **212** of the edge exposure tool **100** to adjust the one or more parameters of the edge exposure lens **110** includes causing the lens adjustment device **212** of the edge exposure tool **100** to adjust a distance **310** between the edge exposure lens **110** and the wafer **104** based on the one or more edge exposure lens adjustment parameters. In a second implementation, alone or in combination with the first implementation, causing the lens adjustment device **212** of the edge exposure tool **100** to adjust the one or more parameters of the edge exposure lens **110** includes causing the lens adjustment device **212** of the edge exposure tool **100** to adjust a horizontal position **312** of the edge exposure lens **110** based on the one or more edge exposure lens adjustment parameters.

In a third implementation, alone or in combination with one or more of the first and second implementations, determining the one or more edge exposure lens adjustment parameters includes determining the one or more edge exposure lens adjustment parameters based on one or more cycle-to-cycle tuning parameters for the edge exposure tool **100** (e.g., as described above in connection with FIG. **5**). In a fourth implementation, alone or in combination with one or more of the first through third implementations, determining the one or more edge exposure lens adjustment parameters based on the one or more cycle-to-cycle tuning parameters includes determining one or more target edge exposure lens parameters for the edge exposure lens **110** based on the one or more cycle-to-cycle tuning parameters (e.g., as described above in connection with FIG. **5**), and determining the one or more edge exposure lens adjustment parameters based on the one or more target edge exposure lens parameters and one or more initial edge exposure lens parameters (e.g., as described above in connection with FIG. **5**).

In a fifth implementation, alone or in combination with one or more of the first through fourth implementations, the one or more cycle-to-cycle tuning parameters include at least one of a lens life of a lens section **210** included in the edge exposure lens **110**, a lens shutter life of one or more lens shutters included in the edge exposure lens **110**, an exposure mode of the edge exposure tool **100**, or a chuck vacuum filter life of a chuck vacuum filter included in the edge exposure tool **100**. In a sixth implementation, alone or in combination with one or more of the first through fifth implementations, the one or more cycle-to-cycle tuning parameters include at least one of a lens optical fiber life of an optical fiber cable included in the edge exposure tool **100**, a lens lamp life of the radiation source **230** included in the edge exposure tool **100**, an exposure distance **118** between an exposure field **116** of the edge exposure lens **110** and the edge of the wafer **104**, or a leveling status of a vacuum chuck **102**, included in the edge exposure tool **100**, on which the wafer **104** is positioned.

In a seventh implementation, alone or in combination with one or more of the first through sixth implementations, the one or more edge exposure lens adjustment parameters include at least one of the distance **310** between the edge exposure lens and a top surface of the wafer **104**, a vertical position **308** of a first section **208** of the edge exposure lens **110**, a vertical position **306** of a second section **208** of the edge exposure lens **110**, or the horizontal position **312** of the edge exposure lens **110**. In an eighth implementation, alone or in combination with one or more of the first through seventh implementations, the one or more edge exposure lens adjustment parameters include the distance **310** between the lens section **210** of the edge exposure lens **110** and a top surface of a photoresist layer **114** on the wafer **104**, and determining the one or more edge exposure lens adjustment parameters includes determining the distance **310** based on at least one of a thickness of the wafer **104**, a thickness of the photoresist layer **114**, or the exposure field **116** for the wafer **104**.

In a ninth implementation, alone or in combination with one or more of the first through eighth implementations, process **600** includes determining (e.g., by the controller) a vacuum intensity for the vacuum chuck **102** configured to support and rotate the wafer **104**. In a tenth implementation, alone or in combination with one or more of the first through ninth implementations, process **600** includes determining (e.g., by the controller) one or more exposure control parameters, for the wafer **104** to be processed by the edge exposure tool **100**, based on at least one of a thickness of the

photoresist layer **114** on the wafer **104** or an amount of fogging of the lens section **210** of the edge exposure lens **110**.

In an eleventh implementation, alone or in combination with one or more of the first through tenth implementations, the one or more exposure control parameters include at least one of a reference exposure intensity for the radiation **112** that is to be directed toward the wafer **104** by the edge exposure lens **110**, a lower exposure intensity for the radiation **112** that is to be directed toward the wafer **104** by the edge exposure lens **110**, a shutter opening delay for the edge exposure lens **110**, a shutter closing delay for the edge exposure lens **110**, or an exposure rotation time for the wafer **104**.

In a twelfth implementation, alone or in combination with one or more of the first through eleventh implementations, process **600** includes receiving (e.g., by the controller **120**), from a position sensor **228***a*, position information associated with the first lens adjustment element **216**, determining (e.g., by the controller **120**) an initial vertical position of the first section **206** based on the position information associated with the first lens adjustment element **216**, determining (e.g., by the controller **120**) an adjusted vertical position for the first section **206** based on the initial vertical position, and providing (e.g., by the controller **120**), to the adjustment motor **224***a*, a signal to cause the adjustment motor **224***a* to move the first lens adjustment element **216** along the elongated support member **214** such that the first section **206** is moved to the adjusted vertical position. In a thirteenth implementation, alone or in combination with one or more of the first through twelfth implementations, process **600** includes determining (e.g., by the controller) at least one of the one or more first adjustment parameters or the one or more second adjustment parameters using at least one of a machine learning model or an artificial neural network.

Although FIG. **6** shows example blocks of process **600**, in some implementations, process **600** may include additional blocks, fewer blocks, different blocks, or differently arranged blocks than those depicted in FIG. **6**. Additionally, or alternatively, two or more of the blocks of process **600** may be performed in parallel.

In this way, an edge exposure tool includes a lens adjustment device. The lens adjustment device is capable of automatically adjusting various parameters of an edge exposure lens of the edge exposure tool to account for changes in operating parameters of the edge exposure tool over time and from cycle to cycle. The edge exposure tool may include a controller that is capable of determining one or more edge adjustment parameters for the edge exposure lens and one or more exposure control parameters for the edge exposure tool using techniques such as big data mining, machine learning, and neural network processing. The lens adjustment device and the controller are capable of reducing and/or preventing the performance of the edge exposure tool from drifting out of tolerance, which can maintain the operation performance of the edge exposure tool and reduce the likelihood of wafer scratching. Moreover, the lens adjustment device and the controller may reduce the downtime of the edge exposure tool that would otherwise be caused by cleaning and calibration of the edge exposure lens, which increases the productivity and throughput of the edge exposure tool.

As described in greater detail above, some implementations described herein provide an edge exposure tool. The edge exposure tool includes an edge exposure lens. The edge exposure tool includes a lens adjustment device configured to automatically adjust one or more parameters of the edge exposure lens based on one or more edge exposure lens adjustment parameters.

As described in greater detail above, some implementations described herein provide a method. The method includes determining, by a controller of an edge exposure tool, one or more edge exposure lens adjustment parameters for an edge exposure lens of the edge exposure tool. The method includes causing, by the controller, a lens adjustment device of the edge exposure tool to adjust one or more parameters of the edge exposure lens based on the one or more edge exposure lens adjustment parameters. The method includes causing, by the controller, the edge exposure lens to direct radiation toward a wafer at or approximately near an edge of the wafer after the one or more parameters of the edge exposure lens are adjusted.

As described in greater detail above, some implementations described herein provide an edge exposure tool. The edge exposure tool includes a vacuum chuck configured to support a wafer. The edge exposure tool includes an edge exposure lens configured to direct radiation toward an edge of the wafer when the vacuum chuck rotates the wafer, including a first section, and a second section interfaced with the first section; and The edge exposure tool includes a lens adjustment device including a first lens adjustment element configured to automatically adjust one or more first parameters of the first section, and a second lens adjustment element configured to automatically adjust one or more second parameters of the second section.

The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. An edge exposure tool, comprising:
- a lens adjustment device comprising:
  - a first lens adjustment element that comprises:
    - a first housing,
    - a first support arm attached to the first housing, and
    - a first position sensor mounted to the first support arm; and
  - a second lens adjustment element that comprises:
    - a second housing,
    - a second support arm attached to the second housing, and
    - a second position sensor mounted to the second support arm; and
- a controller configured to:
  - cause one or more parameters of an edge exposure lens to be adjusted based on one or more edge exposure lens adjustment parameters.

2. The edge exposure tool of claim **1**, wherein the controller, to cause the one or more parameters of the edge exposure lens to be adjusted, is configured to at least one of:
- cause a vertical position of the edge exposure lens to be adjusted, or
- cause a horizontal position of the edge exposure lens to be adjusted.

3. The edge exposure tool of claim 1, wherein the edge exposure lens comprises:
a first adjustable section, and
a second adjustable section.
4. The edge exposure tool of claim 3, wherein the second adjustable section is configured to be inserted in to the first adjustable section.
5. The edge exposure tool of claim 4, wherein the edge exposure lens further comprises:
a lens section attached to the second adjustable section.
6. The edge exposure tool of claim 3, wherein the first lens adjustment element configured to support the first adjustable section; and
wherein the second lens adjustment element configured to support the second adjustable section.
7. The edge exposure tool of claim 1, wherein the controller is further configured to:
determine a distance between the edge exposure lens and a top surface of a photoresists layer on a wafer based on at least one of:
a thickness of the wafer,
a thickness of the photoresist layer, or
an exposure field for the wafer.
8. A method, comprising:
determining, by an edge exposure tool, one or more adjustment parameters for an edge exposure lens;
causing, by the edge exposure tool, the edge exposure lens to be adjusted based on the one or more adjustment parameters,
wherein the edge exposure tool comprises:
a first lens adjustment element that comprises:
a first housing,
a first support arm attached to the first housing, and
a first position sensor mounted to the first support arm; and
a second lens adjustment element that comprises:
a second housing,
a second support arm attached to the second housing, and
a second position sensor mounted to the second support arm; and
causing, by the edge exposure tool, the edge exposure lens to direct radiation toward a wafer at or approximately near an edge of the wafer after the edge exposure lens is adjusted.
9. The method of claim 8, wherein causing the edge exposure lens to be adjusted comprises:
causing a distance between the edge exposure lens and the wafer to be adjusted.
10. The method of claim 8, wherein causing the edge exposure lens to be adjusted comprises:
causing a horizontal position of the edge exposure lens to be adjusted by moving the second support arm inward or outward.
11. The method of claim 8, wherein causing the edge exposure lens to be adjusted comprises:
causing one or more sections of the edge exposure lens to be adjusted at least one of vertically or horizontally.
12. The method of claim 8, further comprising:
determining a target position of the edge exposure lens; and
wherein causing the edge exposure lens to be adjusted comprises:
causing the edge exposure lens to be adjusted based on the target position of the edge exposure lens.
13. The method of claim 8, further comprising:
determining a target position of one or more components of the edge exposure lens; and
wherein causing the edge exposure lens to be adjusted comprises:
causing the edge exposure lens to be adjusted based on the target position of the one or more components.
14. The method of claim 8, wherein determining the one or more adjustment parameters comprises:
determining one or more cycle-to-cycle tuning parameters for the edge exposure tool.
15. An edge exposure tool, comprising:
an edge exposure lens configured to direct radiation toward an edge of a wafer, wherein the edge exposure lens comprises:
a first section, and
a second section interfaced with the first section; and
a lens adjustment device comprising:
a first lens adjustment element configured to adjust the first section, wherein the first lens adjustment element comprises:
a first housing,
a first support arm attached to the first housing and configured to support the first section, and
a first position sensor mounted to the first support arm; and
a second lens adjustment element configured to adjust the second section, wherein the second lens adjustment element comprises:
a second housing,
a second support arm attached to the second housing and configured to support the second section, and
a second position sensor mounted to the second support arm.
16. The edge exposure tool of claim 15, wherein the edge exposure lens further comprises:
a lens section interfaced with the second section.
17. The edge exposure tool of claim 15, wherein the lens adjustment device further comprises:
an elongated support member configured to support the first lens adjustment element and the second lens adjustment element.
18. The edge exposure tool of claim 17, wherein the first lens adjustment element further comprises:
a motor configured to move the first lens adjustment element along the elongated support member.
19. The edge exposure tool of claim 18, further comprising:
a controller configured to:
provide, to the motor, a signal to cause the motor to move the first lens adjustment element along the elongated support member.
20. The edge exposure tool of claim 15, further comprising:
a motor mounted to the first housing; and
a controller configured to:
provide, to the motor, a signal to cause the motor to move the first support arm inward or outward from the first housing.

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